Pollution Loading from Illicit Sewage Discharges in Two Mid-Atlantic Subwatersheds and Implications for Nutrient and Bacterial Total Maximum Daily Loads

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Abstract

The Center for Watershed Protection (Center) collaborated with local jurisdictions to comprehensively detect and quantify the nutrient and bacterial loads from nonstormwater discharges in two Mid-Atlantic subwatersheds. Water quality analyses indicate that the discharges are probably from sewage sources and appear to be a significant, yet unaccounted for, source of pollution to the Chesapeake Bay and its tributaries. The discharges represent a controllable source of pollution whose systematic elimination could result in significant progress toward meeting nutrient and bacterial total maximum daily load (TMDL) reduction requirements.

The Center followed a comprehensive procedure for detecting, tracking, and eliminating pollution sources that included (1) using threshold criteria, such as ammonia and bacteria to determine the presence of illicit sewage discharges; (2) estimating instantaneous pollutant loadings from the dry weather flowing outfalls; and (3) comparing the illicit sewage discharge pollutant load to the watershed load, as estimated from grab samples taken from a downstream, instream location. This analysis shows that the elimination of illicit sewage discharges has the potential to achieve up to 21% of the estimated TMDL phosphorus reduction, 43% of the estimated TMDL nitrogen reduction, and 51% of the estimated TMDL bacterial reduction in one of the study subwatersheds.

Improvements in illicit discharge detection and elimination programs may help communities achieve their targeted pollutant load reductions and can be an important first step for addressing water quality impairments in urban watersheds. Detecting and tracking illicit discharge sources can be a labor-intensive process for government staff that can potentially be offset through collaborative efforts with watershed organizations and volunteer water quality monitoring programs.

Introduction

Studies have shown that dry weather flows from the storm drain system may contribute more than wet weather stormwater flows to the annual discharge mass for some pollutants (US Environmental Protection Agency [USEPA] 1983b; Duke 1997; Pitt and McLean 1986). McPherson et al. (2005) found that dry weather flow in the Ballona Creek watershed in Los Angeles, California, contributed more than 40% of the pollutant loading for each of the following constituents: nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, and total phosphorus (TP). Dry weather flows can stem from car wash discharges, water main breaks, and illicit sewage discharges, among other sources.

In particular, the cumulative illicit sewage discharges into a storm drain system can have a significant water quality impact by introducing high nutrient and bacterial loads with toxic and pathogenic effects. They are often missed by ineffective and/or inefficiently implemented municipal separate storm sewer system (MS4) illicit discharge detection and elimination (IDDE) programs because such programs target larger storm drain or sewer issues (e.g., by limiting illicit discharge monitoring to pipes greater than 36 inches[1] [91.4 cm] in diameter). Furthermore, sewage discharges are relatively small, but persistent, problems that are often not considered part of the large capital improvement projects required under USEPA consent decrees to manage sanitary sewer overflows (SSOs). Finally, although a part of each National Pollutant Discharge Elimination System (NPDES) MS4 permit requires an IDDE program, incentives for implementing *effective* IDDE programs are lacking. For example, the USEPA Chesapeake Bay Program does not currently have a system for crediting local governments that fix illicit discharges through the total maximum daily load (TMDL) process. And in some instances, regulators developing TMDLs assume that

[1] English units have been used throughout this paper due to their common use in engineering and infrastructure applications. Metric equivalents or example conversions are provided.

loadings from sewage discharges will be addressed through actions such as consent decrees. For this reason, they do not "count" loadings from illicit discharges or include them in the background waste load from urban runoff. Therefore, a best management practice (BMP) that eliminates this source, such as IDDE, cannot be credited as part of nutrient load reductions. Local governments find themselves scrambling to undertake the enormous task of nutrient accounting for practices and programs in highly urban landscapes, where substantial benefit could be achieved through the investment of resources into sewage discharge elimination. Benefits could be seen in terms of water quality improvements as well as agency credit for eliminating pollution sources. When federal and state regulatory agencies either fail to understand the importance of the issue or lack the resources to adequately address it, program implementation at the local level can become more of a "check the box" strategy rather than an actual tool to be used for improving water quality.

The purpose of this paper is to present data from two case studies showing that water quality goals in some watersheds may be achieved only if dry weather illicit sewage discharges are addressed within the overall watershed restoration framework. By quantifying dry weather pollutant loading from illicit sewage discharges in two subwatersheds, this paper illustrates the pervasiveness and cumulative impact of dry weather illicit sewage discharges along with the potential value of IDDE as a BMP for achieving goals set forth in TMDLs for impaired waters. Furthermore, this paper presents watershed management implications and recommendations related to sewage discharge elimination based on results from the case studies. In particular, we recommend increasing the priority of sewage discharge elimination within the overall strategy for watershed restoration.

Regulatory Background

Uncontrolled or unpermitted sewage leaks and discharges come under the broad regulatory heading of "illicit discharge." The NPDES Program defines an illicit discharge as "any discharge to a municipal separate storm sewer that is not composed entirely of stormwater, except discharges pursuant to a NPDES permit and discharges resulting from fire-fighting activities." 40 CFR 122.26(b)(2) (1999). NPDES permits may also authorize discharges as long as permit requirements, such as established effluent limits, are being met.

Each Phase I and Phase II MS4 is required to develop and implement a stormwater management program to reduce contamination of stormwater runoff and prohibit illicit discharges. The stormwater management program must include an IDDE program with three primary components—detection, tracking, and elimination of illicit discharges. As part of its IDDE program, each Phase I and Phase II MS4 should have an outfall screening program, education measures, a local ordinance prohibiting illicit discharges, and measurable goals. The programs of Phase I versus Phase II MS4s differ in two main ways. First, Phase I MS4s are explicitly required to screen "major" outfalls—that is, those greater than 36 inches (91.4 cm) in diameter, whereas Phase II MS4s do not have this requirement. Second, Phase I MS4s must use a very prescriptive set of water quality parameters for screening, whereas, in many states (e.g., Maryland, Pennsylvania, and Illinois), Phase II MS4s are not required to conduct water quality testing as part of the screening program.

Stormwater and Wastewater History

Understanding the potential impact of illicit sewage discharges on receiving water quality requires an awareness of the nexus between the sanitary sewer and stormwater pipe networks. Sewer systems are either separate or combined. Combined sanitary systems (CSS) are pipe networks that convey stormwater and sewage together. The comingled flow is transported to a wastewater treatment plant except when large storm flows exceed the capacity of the conveyance system or pipe network. In such cases, the excess untreated sewage–stormwater mixture is diverted to a nearby water course; this is referred to as a combined sewer overflow (CSO).

In separate sanitary sewage (SSS) systems, sewage and stormwater are conveyed in separate pipe networks. Sewage is collected from homes, businesses, and industries and conveyed to a wastewater treatment plant—without mixing with stormwater, at least in theory. In the early 1900s, SSS replaced the CSS as the predominant type of conveyance system in the United States. While more advanced than CSS, decades of neglect have resulted in systemic deterioration of SSS that allows groundwater and stormwater to enter these systems through breaks and leaks in the pipe network. As a result of inflow and infiltration, large storm events, and other causes, USEPA estimates at least 23,000–75,000 sanitary sewer overflows (SSOs) per year (not including sewage backups into buildings; USEPA 2004). Most large SSS communities with SSO issues are regulated by state agencies and/or USEPA under consent actions that require structural repairs and proactive maintenance. Receiving waters served by SSS are plagued by small leaks, breaks, and maintenance-related discharges (clogging with grease) that are easily overlooked by sewer evaluations. Sewer evaluations also can overlook direct discharges of sewage into the storm drainage system from individual homes and businesses. These discharges—which can be easily identified through IDDE programs—are a major source of bacterial and nutrient impairment.

Communities across the United States are spending billions of dollars to address CSOs and SSOs through repairs or sewer capacity expansions intended to reduce major overflows that occur primarily during storm events. However, recent studies by Kaushal et al. (2011) and the Center (CWP 2011) cast doubt on whether such efforts are adequate to address all sewage-related impacts to water quality. These studies were conducted in the City of Baltimore, Maryland, a community served by an SSS. In response to a consent decree, Baltimore has spent millions of dollars on wet weather repairs to address SSOs (City of Baltimore 2010), but both studies indicate that these repairs have had little impact on *dry weather* discharges. Specifically, Kaushal et al. (2011) studied six urban tributaries in the Baltimore region. Using stable isotopic techniques, they found that sewage was the predominant source of nitrogen load during baseflow conditions, even after repairs to the wastewater system were complete. Similarly, a restoration plan for Baltimore Harbor found little or no improvement in nutrient or bacterial loading after years of sewer system repairs in Baltimore that targeted infrastructure limitations causing wet weather SSOs (CWP 2011). The authors determined that this finding was due to the underlying persistent pollution loads from dry weather sewage sources.

The persistence of water course impairments, despite substantial investments in infrastructure repair, is due, in part, to scale. Municipal programs that aim to eliminate CSOs and SSOs predominantly target wet weather events through the repair and replacement of pipes and pumping stations. Although dry weather occurrences are addressed through proactive operation and maintenance protocols, as specified in consent decrees, widespread small sewage leaks continue to discharge to surface waters. This is the case especially for sewer laterals—that is, private connections to homes and businesses that are often connected to the municipal system by private contractors with limited public oversight.

Case Study Descriptions

This study included estimates of illicit sewage discharge pollution loads for two Chesapeake Bay subwatersheds: Western Run, a 5.4-square-mile (mi^2; 12.9-km^2) subwatershed in northwestern Baltimore City, and Sligo Creek, a 9.6-mi^2 (24.9-km^2) subwatershed in Montgomery County, Maryland, just north of the District of Columbia (Figure 1). Both watersheds drain low- to medium-density residential land uses (Table 1) on the outskirts of major metropolitan areas. These watersheds are typical of many urban streams with limited floodplain connectivity, armored banks, channel incision, and impaired water quality (in terms of bacteria, sediment, and nutrients; see Table 2). Each subwatershed is within a Phase I MS4 jurisdiction and therefore regulated for illicit discharges. The City of Baltimore and Montgomery County implement IDDE programs in Western Run and Sligo Creek, respectively.

Figure 1. Two subwatershed case studies: Western Run and Sligo Creek. Image courtesy of Google Maps.

Table 1. Size and land use distribution of sampled watersheds.

Subwatershed	Area (mi^2)	Impervious Cover (%)	Percentage Land Use in Watershed					
			Commercial	High-Density Residential	Medium-Density Residential	Low-Density Residential	Open Space	Other
Western Run	5.4	~33.0	3.9	7.1	27.0	41.5	2.2	18.3
Sligo Creek	9.6[a]	33.6	6.5	11.8	60.6	—	—	21.1

[a] This area reflects only the Montgomery County portion of the watershed.
Note: 1 mi^2 = 2.6 km^2

Table 2. Water quality impairments in sampled watersheds.

TMDL	Anacostia (Sligo Creek)	Jones Falls (Western Run)
Bacteria	X	X
Sediment	X	X
Nutrients	X	X
PCBs	X	
Trash	X	
Zinc		X
Copper and Lead		X

Note: PCBs, polychlorinated biphenyls.

Methods

The methods included collecting flow and water quality data from storm drain outfalls and instream locations in each subwatershed over several days within a two-week period. Fieldwork took place in June 2010 for Western Run and January 2011 for Sligo Creek. Teams of three to four Center and local government staff, along with watershed group volunteers visited all outfalls in the subwatershed by walking entire stream reaches. Using the outfall reconnaissance inventory technique described by Brown et al. (2004), the teams investigated outfalls with dry weather flow and screened them for a number of illicit discharge indicators, including physical indicators, such as pipe benthic growth, odor, flow lines, and cracking or spalling (flaking or chipping) of the pipe; bacteria; and chemical indicators, specifically ammonia, detergents, potassium, and fluoride. The teams collected three samples from each flowing outfall and analyzed them as indicated in Table 3. Sample collection methods included conditioning the sample bottle with dry weather flow (i.e., rinsing the sample bottle several times with sample water before collection) and then directly filling a single bottle by holding it under the discharge from each drain until the bottle was full. We also collected instream grab samples on only one day and analyzed them for total nitrogen (TN) and TP.

The teams took a flow measurement at each outfall using either a timed volumetric method, cross-section–velocity method, or weir equation[2] (depending on the conditions at a given location). Teams also collected instream flow measurements in the upper, middle, and lower regions of each watershed using a pygmy meter. Standard conversions and assumptions for outfalls (i.e., that flow remained constant over the entire day) allowed for daily flow estimates.

We adjusted the grab sample concentrations by subtracting a background surface water concentration of TN (1.0 mg/L) and TP (0.02 mg/L) for each grab sample to provide a conservative estimate of pollutant load. The background nutrient concentrations are based on data collected by the US Geological Survey's National Water-Quality Assessment program in natural watersheds (average TN = 0.26 mg/L; average TP = 0.022 mg/L; Clark et al. 2000) as well as data collected by Center staff from "clean" outfalls—that is, those that did not exceed illicit discharge screening parameter thresholds—in Baltimore, Maryland (average TN = 2.0964 mg/L; average TP = 0.0539 mg/L; Lilly and Sturm 2010). We used the adjusted concentrations to estimate an annual load with the assumption that the illicit discharge flow rate remained constant over an entire year. The diurnal and weekly variations in outfall discharges, however, may skew the estimates of the cumulative outfall discharge, in contrast to the estimates from the instream grab samples. Likewise, temporal and seasonal differences, as well as differences in land cover and riparian characteristics of the subwatersheds, probably contributed to differences observed between the subwatersheds. Further sampling could address these issues. Although one should use extrapolated estimates with caution, they are useful for estimating the potential contribution of the sewage discharge to the total loading. The limited budget of this project could not accommodate a more frequent and regular monitoring program that would have allowed for more accurate quantification of seasonal/diurnal variability and refined annual load rates.

We used a variation of the flow chart method (Brown et al. 2004) to distinguish among three major types of discharges: wastewater, wash water, and tap water (Figure 2). Subsequently, teams tracked these discharges to their sources when possible. When the threshold levels were not exceeded, we assumed that the source was groundwater and was not composed of sewage, wash water, or tap water. The flow chart method helped determine the presence of a potential illicit discharge and loading from suspect outfalls. Wastewater (sewage) discharges include sanitary wastes, as indicated by the presence of detergents or other surfactants and high ammonia concentrations. Wash water discharges can include domestic wash water (e.g., from a cross-connected washing machine) as well as a wide range of industrial process waters. Detergents are typically present in wash water, but the ratio of ammonia to potassium is generally lower than that found in wastewater. Tap water

[2] Flow = [3.1 × wetted width (feet) × depth (feet)]1.5. This method was used only with a free-flowing outfall and when the depth of flow was relatively uniform.

Table 3. Water quality sample analysis.

Sample	Parameter Analyzed	Equipment	Method	Location	Specifications	Notes
Field Measurement	Ammonia	Hannah HI 93715 or Milwaukee MI405	Adaptation of the Nessler method (USEPA 1979, method no. 350.2)	Field	Range: 0.1–9.99 mg/L Accuracy: ± 0.1 mg/L	Meter zeroed with sample water before each measurement
Sample 1	Fluoride	Hannah HI 93729 Low-Range Photometer	Adaptation of the SPADNS method (USEPA 1979, method no. 340.1)	Baltimore City's Ashburton lab, Baltimore, MD, or Maryland National Capital Park and Planning Commission lab	Range: 0–2.00 mg/L Resolution: 0.01 mg/L Precision: ± 0.03 mg/L at 1.00 mg/L	Meter zeroed before each reading using a standard created with distilled water reacted with reagent
	Anionic surfactants	Chemetrics Detergent Kit	USEPA (1983a) method no. 425.1		Range: 0–3 ppm	
	Potassium	Horiba Cardy Compact Ion Meter C-131	As per manufacturer: nitrate ion electrode method		Range: 0–99 · 100 ppm; Resolution: 1.0 ppm (0–99 ppm), 100 ppm (10–99 ·10 ppm), and 100 ppm (10–99 · 100 ppm)	Two-point calibration conducted before each set of sample readings, where the meter was standardized first to 20 x 100 ppm and then to 15 x 10 ppm
Sample 2	TN	—	USEPA (1979) method no. 353.2	Contracted to Chesapeake Bay lab (Solomons, MD) and Horns Point lab (Cambridge, MD) for analysis	Labs undergo a blind audit; average percentage difference of the analysis compared to the prepared reference concentration, which is between 5% and 10%	Samples frozen at end of field day and mailed on ice to the lab
	TP	—	USEPA (1979) method no. 353.2			
Sample 3	*E. coli* and total coliform	3M Petrifilm plates	As per manufacturer: Incubated at approximately 35°C for 24 hours ± 1 hour; red and blue colonies with gas enumerated manually or with a 3M Plate Reader	Center office in Ellicott City, MD		100 mL of sample collected in a sterile bottle and plated no more than six hours after collection; a 1-mL subsample plated to grow *E. coli* as "blue" colonies and total coliform as "red" colonies; the colonies of each are counted, multiplied by 100 and reported as colony forming units, or CFUs, per 100 mL

Notes: Hanna Instruments, Smithfield, RI; Chemtrics, Inc, Midland, VA; Horiba Instruments Inc, Irvine, CA; 3M Microbiology Products, St Paul, MN.

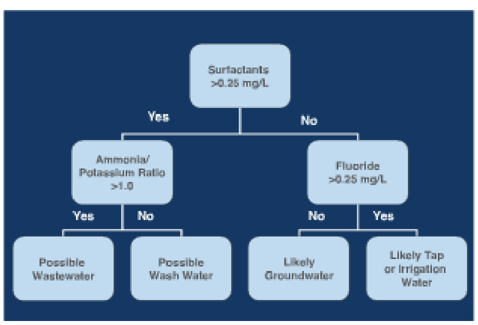

Figure 2. Flow chart method used to distinguish among potential illicit discharges. Source: Brown et al. 2004.

(which includes no detergents) often originates from a broken water line and, although not illicit, is often a target repair for a community.

Threshold levels for illicit discharge screening parameters, defined in Table 4, stem primarily from research conducted for the preparation of an IDDE guidance manual for Phase II MS4s (Brown et al. 2004). If an illicit discharge was suspected based on the initial sampling, typically one team (designated the "tracking team") would immediately leave the stream and attempt to track the source of the contaminated flow to the source. The team would conduct visual screening and chemical monitoring in the upstream storm drain network to attempt to confirm the source of the illicit discharge.

Table 4. Threshold levels for screening parameters used in outfall screening.

Parameter	Threshold	Source
Ammonia	>0.1 mg/L	Brown et al. (2004)
E. coli	235 CFU/100 mL (grab sample)	USEPA (1986)
Total coliform	10,000 CFU/100 mL (grab sample)	California state standard (Dorfman and Rosselot 2011)
Fluoride	0.25 mg/L	Brown et al. (2004)
Detergents	0.25 mg/L	Brown et al. (2004)
Potassium	5 ppm	Guidance extrapolated from Lilly and Sturm (2010)

Measuring TN and TP concentrations at the outfall, along with flow, allowed for a quantification of the nutrient load from individual outfalls suspected of having sewage contamination. For example, outfall CCA8 from Sligo Creek had an ammonia concentration of 3.62 mg/L, a detergent concentration of 0.75 mg/L, and 15,000 colony forming units (CFU) of *Escherichia coli* per 100 mL. These concentrations are much higher than one would find in ambient stream or groundwater conditions and are most likely due to the presence of sewage. TN measured at this outfall was 6.5 mg/L and flow was 0.05 cubic feet per second (cfs) (0.0014 m^3/s). A conservative nitrogen load estimate, made by subtracting 1.0 mg/L from the original concentration, gives a final estimated annual load, using standard conversions[3], of 539 pounds/year (244 kg/year).

Case Study Results: Western Run and Sligo Creek

Illicit sewage discharges were pervasive in the two case study watersheds. Of the 313 outfalls assessed, 103 (33%) had dry weather flow (Table 5). Of the outfalls with dry weather flow, 78% exceeded water quality parameters that indicate the presence of illicit discharges. Ammonia, the primary wastewater indicator, was present in half of the discharges investigated. Approximately 40% of the discharges contained fluoride, a potable (i.e., tap) water indicator. Detergents, indicators of wash water or wastewater, were present in one-third of the discharges. More than one-third of all discharges had *E. coli* concentrations above the USEPA (1986) threshold for contact recreation, and half of the flowing outfalls in Western Run exceeded *E. coli* thresholds.

Discharge

The cumulative discharge from all suspected storm drain outfalls in Sligo Creek was approximately 1.35 million gallons/day (5,110 m^3/day)—approximately equal to the total instream discharge (1.26 million gallons/day [4,770 m^3/day]). In contrast, the stormwater outfall discharge in Western Run (0.25 million gallons/day [946 m^3/day]) was only 9% of the total instream discharge (2.77 million gallons/day [10,486 m^3 /day]).

Nutrients

Based on the downstream instream flow and nutrient sample collection in each subwatershed, the estimated daily nitrogen load was 24–31 pounds/day (10.9–14.1 kg/day) and the daily phosphorus load was 0.15–1.0 pounds/day (0.068-0.45 kg/day); (Table 6). In Sligo Creek, the TN load from outfalls suspected of having illicit discharges made up 97% of the instream load, and phosphorus loadings from suspected discharges composed more than 500% of the

Table 5. Outfall summary.

	Sligo Creek	Western Run	Sum
Total outfalls assessed	213	100	313
Outfalls with dry weather flow	58 (27%)	45 (45%)	103 (33%)
No. of discharges exceeding threshold levels for ammonia, fluoride, or detergents	47 (80%)	33 (73%)	80 (78%)
No. of discharges with potential wastewater or other discharge of unknown origin (ammonia >0.1 mg/L)	35 (60%)	16 (36%)	51 (50%)
No. of potential tap water discharges (fluoride >0.25 mg/L)	17 (29%)	23 (51%)	40 (39%)
No. of potential wash water discharges (anionic surfactants >0.25 mg/L)	24 (41%)	11 (24%)	35 (34%)
Outfalls with *E. coli* above USEPA threshold for contact recreation (>235 CFU/100 mL)	14 (24%)	24 (53%)	38 (37%)

[3] Pounds per cubic foot = (nitrogen concentration × 28.317)/453,592; pounds per year = pounds per cubic foot × cfs × 31,557,600. 1 pound = 0.454 kg and 1 cubic foot = 0.028 cubic meters.

instream load. In Western Run, the TN load from outfalls suspected of having illicit discharges made up 17% of the instream load, and phosphorus loadings from suspected discharges composed 58% of the instream load. Instream flow measurements in each subwatershed were collected only on day 1 of the outfall screening. In each subwatershed, outfall screening took place on multiple field days over an approximately two-week period. The refinements needed in sampling methods for calculating load estimates may overcome the limitations of this study that resulted in the phosphorus outfall load exceeding the instream load in Sligo Creek.

Table 6. Instream sample (farthest downstream point).

	Sligo Creek	Western Run
Ammonia (mg/L)	N/A	0.13
E. coli (CFU/100 mL)	100	20,000
Discharge (cfs)	1.9	4.3
TN (mg/L)	2.4	1.3
TN Load (pounds/day)	2.4	31.0
TP (mg/L)	0.02	0.04
TP Load (pounds/day)	0.2	1.0

Bacteria

The downstream instream bacterial concentration was much higher in Western Run (20,000 CFU/100 mL) than in Sligo Creek (100 CFU/100 mL), probably because of a large sewer line break found upstream of the instream monitoring location during the sampling in Western Run. Average *E. coli* concentrations from outfalls were high in both subwatersheds: 1,345 CFU/100 mL in Sligo Creek and 321,462 CFU/100 mL in Western Run. The majority of outfall *E. coli* came from those outfalls that exceeded illicit discharge parameter thresholds. For example, 96% of the *E. coli* from outfalls in Sligo Creek and 87% of the *E. coli* from outfalls in Western Run came from those outfalls that were suspected of having illicit discharges.

Tracking Sources

Tracking the source of illicit discharges may be straightforward and even obvious in some cases; however, in other cases, a lot of detective work is required. Many of the illicit discharges in Western Run were tracked to specific sources. In one instance, dye testing confirmed that a sewage discharge resulted from leakage from the sanitary system into the storm drain system. In another instance, sewage discharge was confirmed from a broken sanitary pipe. In Sligo Creek, a handful of the 47 potential discharges initially found through field screening have been successfully tracked to a source. One investigation required approximately 55 total staff hours; the effort was complicated by the fact that the source was a blend of at least four different sewage sources. Several source investigations are ongoing.

Management Implications and Recommendations

The elimination of a watershed's illicit discharges may have significant cost and management implications if considered as part of watershed-wide pollutant load reductions. The results of this study suggest that (1) IDDE can play a significant role in meeting TMDL requirements; (2) IDDE, although labor-intensive, is a cost-effective way to meet pollutant load targets; (3) detection and load estimation methods must be refined; (4) municipalities can work with the volunteer monitoring community to find illicit discharges; and (5) finding and removing sources requires significant coordination and persistence among local agencies.

IDDE Can Play a Significant Role in Meeting TMDL Requirements

IDDE is a tool that can be used to identify sewage discharges and meet both bacterial and nutrient TMDLs in local waterways. For example, although Western Run itself has no specific nutrient impairment, the City of Baltimore will have to meet jurisdiction-wide nutrient load reduction targets (18% for TN and 34% for TP) as part of the State of Maryland's strategy to address the Chesapeake Bay nutrient TMDL (Maryland Phase I Watershed Implementation Plan 2010).[4] Since Western Run is a subwatershed of the Jones Falls watershed, reduction targets were applied to loading estimates from the Lower Jones Falls small watershed action plan (CWP 2006). Comparing the load reductions of 3,015 pounds/year (1,368 kg/year) for TN and 1,025 pounds/year (465 kg/year) for TP to the loadings measured from the illicit discharges, the illicit discharge load for TP, based on the Center's field screening, was 217 pounds/year (98 kg/year) —approximately 21% of the reduction needed for Western Run (Figure 3). The illicit discharge load for TN was 1,897 pounds/year (860 kg/year)—approximately 43% of the reduction needed for the subwatershed (Figure 4). In a similar analysis for Sligo Creek, we found that the illicit discharge load represented 17% of the TN and 6% of the

[4] More refined jurisdiction-wide targets were issued in October, but not in time to be incorporated into this paper.

TP TMDL reduction. The analysis was based on the nutrient TMDL developed for the nontidal Anacostia watershed (Maryland Department of the Environment [MDE] and District of Columbia Department of the Environment 2008), which required an 80% reduction in TP and a 79% reduction in TN.

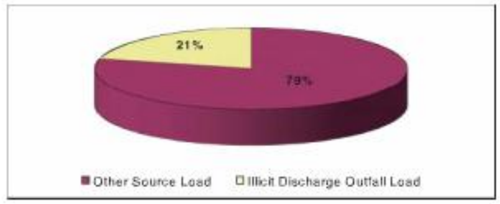

Figure 3. Illicit discharge load as a percentage of TP reduction for Western Run.

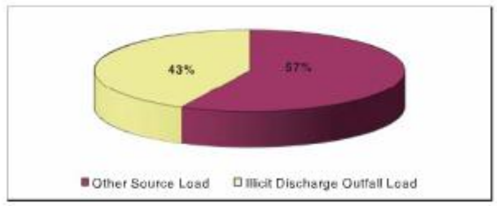

Figure 4. Illicit discharge load as a percentage of TN reduction for Western Run.

MDE developed a fecal coliform TMDL for the Jones Falls watershed in 2006. A baseline load for a subwatershed of the Jones Falls (i.e., subwatershed JON0039) is an estimated 9,152 billion most probable number (MPN)/day. MPN refers to serial dilution tests that measure the concentration of a target microbe in a sample (MDE 2006a). The TMDL allocation for the subwatershed is 430 billion MPN/day—a reduction of 8,722 billion MPN/day. Assuming that the load allocation for Western Run (with an area of 3,478 acres [14 km^2]) is proportional to that of the 7,546-acre (30.5-km^2) TMDL subwatersed, the baseline load for Western Run would be 46% of the baseline load, or 4,210 billion MPN/day. The estimated TMDL allocation for Western Run is therefore 20 billion MPN/day, or a reduction of 4,190 billion MPN/day. The illicit discharge load for bacteria estimated from Center staff field screening is 2,056 billion MPN/day, or 51% of the required bacterial reduction (Figure 5). We conducted a similar analysis for Sligo Creek and the illicit discharge load represented 21% of the bacterial TMDL reduction. The analysis was based on a fecal coliform TMDL developed for the Anacostia watershed (MDE 2006b), which required a 93% reduction for the watershed[5].

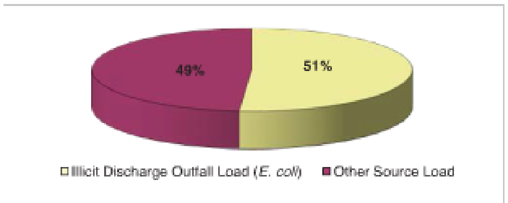

Figure 5. Illicit discharge load as a percentage of total bacterial reduction for Western Run.

This analysis suggests that some pollutant loads may be missed if the right "accounting tools" are not used to identify sources. Consequently, watershed managers and regulating agencies may be misled about the real pollutant load and the stormwater practices and programs that will most effectively reduce the pollutant load. Kaushal et al. (2011) estimated that, although highly variable, approximately 13.5% of the TN load in Baltimore area streams is from sewage sources. Some modelers perceive that pollutant loadings from sewage discharges are intermittent in nature; therefore, such discharges may be considered inconsequential to the total annual stormwater load and not incorporated as a significant source in simulation models. However, the present case studies found that illicit sewage discharges are more widespread and of much longer duration than previously thought. The state of Maryland's SSO database reports that the SSO volume in Sligo Creek from 2005 to 2010 was 224,021 gallons (848 m^3) from blockages and wet weather events. Just one of the illicit discharge flows found through this study had an estimated flow of 32,344 gallons per day (122 m^3) for a total of >9 million gallons (34,069 m^3) in a ten-month period. This is one of more than 40 illicit discharges detected in the field. The cumulative impact of many such problems to receiving waters is noteworthy. More broadly, because the illicit sewage discharge as a source has not been previously accounted for in inputs to the Chesapeake Bay Watershed Model, the actions and strategies needed to address the issue have not been a priority. In an age of pollutant accounting, local governments should be offered incentives for more comprehensively implementing their IDDE programs.

[5] Although the TMDL was developed using fecal coliform as the indicator organism, the State revised the criteria such that it is now based on water column limits for either *E.coli* or enterococci.

IDDE Is an Inexpensive Way To Meet Pollutant Load Targets

The cost of fixing illicit discharges is much less expensive per pound of nutrient reduced than other methods that treat the same load at the end of the pipe. For example, removing the annual nitrogen load associated with potential illicit discharges found in Sligo Creek would conceivably cost 18 times more if done via a practice such as a dry swale (Figure 6). IDDE can be costly in terms of staff time to track down problems, but the water quality benefit that can be achieved outweighs the upfront cost. In addition, as illustrated by Pennington et al. (2003, 1040), "communities are ill advised to rely exclusively on structural BMPs to address their water quality concerns." A holistic approach that effectively integrates both structural and nonstructural practices will be needed to address the many water quality impairments in the United States.

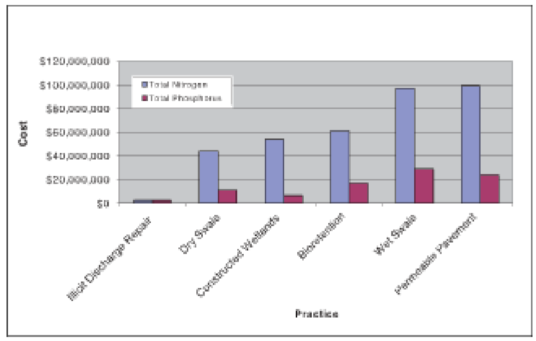

Figure 6. Costs of various practices to treat an equivalent annual load estimated from illicit discharges in Sligo Creek. The estimate for the cost of the illicit discharge repair assumes that each repair will cost \$50,000. The estimates for the cost of constructed wetlands, bioretention, and permeable pavement assume that 100% of the water quality volume is provided to treat 1 inch of rainfall.

To Successfully Identify Discharges, the Detection Methods Are Extremely Important and Need To Be Refined.

As indicated by the results of this study, monitoring for the right parameters is important. Many Phase I communities, in particular, do not monitor for ammonia, one of the best indicators of sewage discharges. Typical monitoring indicators for Phase I communities include pH, temperature, conductivity, chlorine, phenols, and copper. Simply adding ammonia to this list of parameters would go a long way toward identifying more discharges.

In Sligo Creek, teams consisted of at least one Center staff person and one Montgomery County staff person. Staff from each organization used their own illicit discharge monitoring protocols at each outfall (Table 7); this enabled a comparison of the protocols. Use of the Center's monitoring protocols resulted in a significant benefit in terms of the number of discharges found: 22% more additional discharges were detected in Sligo Creek using the Center's protocol compared to that used by the local government. The Center's protocol uncovered approximately 70% more discharges than would have been found using the "standard" Phase 1 set of water quality parameters (which include all of the county's parameters except detergents).

In addition, although physical indicators are important, particularly for identifying the worst discharges, one cannot always rely on physical indicators alone. In other words, actually monitoring suspect flows is a critical first step for virtually all outfalls flowing during dry weather.

Table 7. Illicit discharge monitoring parameter comparison.

CWP	Montgomery County	"Standard" Phase I Jurisdiction
Ammonia Fluoride Detergents Potassium Bacteria	Detergents pH Temperature Copper Phenols Chlorine	pH Temperature Copper Phenols Chlorine

Municipalities Can Work with the Volunteer Monitoring Community To Find These Discharges

Increasingly, citizens are interested in protecting their waterways. The volunteer monitors who worked with Center staff on this project added tremendous value in terms of watershed knowledge and enthusiasm. Although quality control issues can sometimes make it difficult to use regular instream volunteer monitoring, the use of more accessible field and laboratory techniques can be used to guide immediate management decisions. To make this work, the local government must establish good working relationships with local watershed groups so that the government agency can focus limited resources on tracking discharges and removing the source of discharges from suspect outfalls.

Using watershed group staff and/or volunteer monitors as part of the sewage discharge detection process will take training on protocols, methods, and safety, but the challenges are far from insurmountable. Given the sheer number of outfalls in urban areas, the potential breadth of the problem, and the fact that the methods would meet both the MS4 permit requirements and watershed advocacy goals, IDDE partnerships between local governments and watershed groups could go a long way toward finding and fixing sewage discharge problems.

Actually Finding the Source of Discharges Requires Effort and Persistence

The elimination of illicit discharges can be the most challenging goal, and one that needs ongoing commitment. To achieve this goal, communities need to establish an accurate storm drain network map for pipes and outfalls and continue to update it as new geographic information becomes available through monitoring and investigations. Some of the most challenging discharges to find were those from outfalls that did not exist on the stormwater map but carried a discharge. Further, one can often find a disconnect between local wastewater and stormwater agencies; the establishment of a good working relationship between these two agencies will go a long way toward elimination. Increased coordination and sharing of resources (e.g., a sewer camera) between local agencies, such as public works and wastewater utilities, would facilitate efforts to track the sources of illicit discharges.

Conclusions

Illicit sewage discharges into storm drain systems can be a major source of bacteria and nutrients entering urban waterways, despite system-wide improvements to rehabilitate the sewerage system. An investigation in Western Run in the City of Baltimore showed that the elimination of illicit discharges in this subwatershed could potentially meet 21% of the TP, 43% of the TN, and 46% of the bacteria TMDL goals. For Sligo Creek in Montgomery County, a similar analysis showed that the elimination of illicit discharges could potentially meet 6% of the TP, 17% of the TN, and 21% of the bacteria TMDL goals. Although this assessment was based on limited sampling data, the sheer magnitude of the potential load reductions is compelling, especially in light of the potential cost savings apparent from a comparison of load reductions through illicit discharge elimination versus green infrastructure practices for Sligo Creek. More research is needed, especially in estimating flow rates, to better quantify the load reduction potential from illicit sewage discharges.

Regulatory agencies should consider widespread programmatic changes to ensure that MS4 permits require the use of basic tracking tools. As a first task, agencies should develop a comprehensive geographic information system that identifies all storm drains regardless of size. This should be followed by the development of a systematic screening program that monitors all dry weather flows from storm drain outfalls for indicators of sewage, including ammonia and bacteria. Finally, the elimination of sewage discharges into the storm drain system should be the collective responsibility of MS4 permit programs as well as programs addressing SSOs. Staff resources have the potential to be high but may be offset by engaging local watershed groups in the initial screening process where feasible.

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